

Environmental Protection Agency

§ 1065.645

use multiple venturis and you calibrated each combination of venturis, calculate \dot{n} using the sum of the active venturi throat areas as A_t , the sum of the active venturi throat diameters as d_t , and the ratio of venturi throat to inlet diameters as the ratio of the sum of the active venturi throat diameters to the diameter of the common en-

trance to all of the venturis. To calculate the molar flow rate through one venturi or one combination of venturis, use its respective mean C_d and other constants you determined according to § 1065.640 and calculate its molar flow rate \dot{n} during an emission test, as follows:

$$\dot{n} = C_d \cdot C_f \cdot \frac{A_t \cdot p_{in}}{\sqrt{Z \cdot M_{mix} \cdot R \cdot T_{in}}} \quad \text{Eq. 1065.642-6}$$

Example:

$$C_d = 0.985$$

$$C_f = 0.7219$$

$$A_t = 0.00456 \text{ m}^2$$

$$p_{in} = 98836 \text{ Pa}$$

$$Z = 1$$

$$M_{mix} = 28.7805 \text{ g/mol} = 0.0287805 \text{ kg/mol}$$

$$R = 8.314472 \text{ J/(mol} \cdot \text{K)}$$

$$T_{in} = 378.15 \text{ K}$$

$$\dot{n} = 0.985 \cdot 0.712$$

$$\frac{0.00456 \cdot 98836}{\sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 378.15}}$$

$$\dot{n} = 33.690 \text{ mol/s}$$

§ 1065.645 Amount of water in an ideal gas.

This section describes how to determine the amount of water in an ideal gas, which you need for various performance verifications and emission calculations. Use the equation for the vapor pressure of water in paragraph (a) of this section or another appropriate equation and, depending on whether you measure dewpoint or relative humidity, perform one of the calculations in paragraph (b) or (c) of this section.

(a) *Vapor pressure of water.* Calculate the vapor pressure of water for a given saturation temperature condition, T_{sat} , as follows, or use good engineering judgment to use a different relationship of the vapor pressure of water to a given saturation temperature condition:

(1) For humidity measurements made at ambient temperatures from (0 to 100) °C, or for humidity measurements made over super-cooled water at ambient temperatures from (−50 to 0) °C, use the following equation:

$$\begin{aligned} -\log_{10}(p_{H2O}) = & 10.79574 \cdot \left(\frac{273.16}{T_{sat}} - 1 \right) + \\ & 5.02800 \cdot \log_{10} \left(\frac{T_{sat}}{273.16} \right) + \\ & 1.50475 \cdot 10^{-4} \cdot \left(10^{-8.2969 \cdot \left(\frac{T_{sat}}{273.16} \right)} - 1 \right) + \\ & 0.42873 \cdot 10^{-3} \cdot \left(1 - 10^{4.76955 \cdot \left(1 - \frac{273.16}{T_{sat}} \right)} \right) + \\ & 0.21386 \end{aligned} \quad \text{Eq. 1065.645-1}$$

Where:

p_{H2O} = vapor pressure of water at saturation temperature condition, kPa.

T_{sat} = saturation temperature of water at measured conditions, K.

Example:

$$T_{sat} = 9.5 \text{ } ^\circ\text{C}$$

$$T_{dsat} = 9.5 + 273.15 = 282.65 \text{ K}$$

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$$\begin{aligned}
 & -\log_{10}(p_{H2O}) = \\
 & 10.79574 \cdot \left(\frac{273.16}{282.65} - 1 \right) + \\
 & 5.02800 \cdot \log_{10} \left(\frac{282.65}{273.16} \right) + \\
 & 1.50475 \cdot 10^{-4} \cdot \left(10^{-8.2969 \cdot \left(\frac{282.65}{273.16} \right) - 1} \right) + \\
 & 0.42873 \cdot 10^{-3} \cdot \left(1 - 10^{4.76955 \cdot \left(1 - \frac{273.16}{282.65} \right)} \right) + \\
 & 0.21386 \\
 & -\log_{10}(P_{H2O}) = -0.074297 \\
 & p_{H2O} = 10^{0.074297} = 1.1866 \text{ kPa}
 \end{aligned}$$

(2) For humidity measurements over ice at ambient temperatures from (–100 to 0) °C, use the following equation:

$$\begin{aligned}
 & -\log_{10}(p_{\text{sat}}) = \\
 & 9.09685 \cdot \left(\frac{273.16}{T_{\text{sat}}} - 1 \right) + \\
 & 3.56654 \cdot \log_{10} \left(\frac{273.16}{T_{\text{sat}}} \right) + \\
 & 0.87682 \cdot \left(\frac{257.75}{T_{\text{sat}}} - 1 \right) + \\
 & 0.21386 \quad \text{Eq. 1065.645-2}
 \end{aligned}$$

Example:

$$\begin{aligned}
 T_{\text{ice}} &= -15.4 \text{ °C} \\
 T_{\text{ice}} &= -15.4 + 273.15 = 257.75 \text{ K}
 \end{aligned}$$

$$\begin{aligned}
 & -\log_{10}(p_{\text{sat}}) = \\
 & 9.09685 \cdot \left(\frac{273.16}{257.75} - 1 \right) + \\
 & 3.56654 \cdot \log_{10} \left(\frac{273.16}{257.75} \right) + \\
 & 0.87682 \cdot \left(\frac{257.75}{273.16} - 1 \right) + \\
 & 0.21386 \\
 & -\log_{10}(p_{H2O}) = -0.79821
 \end{aligned}$$

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$$P_{H2O} = 10^{0.074297} = 0.15941 \text{ kPa}$$

(b) *Dewpoint.* If you measure humidity as a dewpoint, determine the amount of water in an ideal gas, x_{H2O} , as follows:

$$x_{H2O} = \frac{p_{H2O}}{p_{\text{abs}}} \quad \text{Eq. 1065.645-3}$$

Where:

x_{H2O} = amount of water in an ideal gas.
 p_{H2O} = water vapor pressure at the measured dewpoint, $T_{\text{sat}} = T_{\text{dew}}$.
 p_{abs} = wet static absolute pressure at the location of your dewpoint measurement.

Example:

$$\begin{aligned}
 P_{\text{abs}} &= 99.980 \text{ kPa} \\
 T_{\text{sat}} &= T_{\text{dew}} = 9.5 \text{ °C} \\
 \text{Using Eq. 1065.645-2,} \\
 P_{H2O} &= 1.1866 \text{ kPa} \\
 x_{H2O} &= 1.1866/99.980 \\
 x_{H2O} &= 0.011868 \text{ mol/mol}
 \end{aligned}$$

(c) *Relative humidity.* If you measure humidity as a relative humidity, $RH\%$, determine the amount of water in an ideal gas, x_{H2O} , as follows:

$$x_{H2O} = \frac{RH\% \cdot p_{H2O}}{p_{\text{abs}}} \quad \text{Eq. 1065.645-4}$$

Where:

x_{H2O} = amount of water in an ideal gas.
 $RH\%$ = relative humidity.
 p_{H2O} = water vapor pressure at 100% relative humidity at the location of your relative humidity measurement, $T_{\text{sat}} = T_{\text{amb}}$.
 p_{abs} = wet static absolute pressure at the location of your relative humidity measurement.

Example:

$$\begin{aligned}
 RH\% &= 50.77\% \\
 P_{\text{abs}} &= 99.980 \text{ kPa} \\
 T_{\text{sat}} &= T_{\text{amb}} = 20 \text{ °C} \\
 \text{Using Eq. 1065.645-2,} \\
 P_{H2O} &= 2.3371 \text{ kPa} \\
 x_{H2O} &= (50.77\% \cdot 2.3371)/99.980 \\
 x_{H2O} &= 0.011868 \text{ mol/mol}
 \end{aligned}$$

§ 1065.650 Emission calculations.

(a) *General.* Calculate brake-specific emissions over each test interval in a duty cycle. Refer to the standard-setting part for any calculations you might need to determine a composite result, such as a calculation that weights and sums the results of individual test intervals in a duty cycle. We specify three alternative ways to